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OBSERVATIONS OF WINDS AND CURRENTS IN HOOD CANAL.(U)

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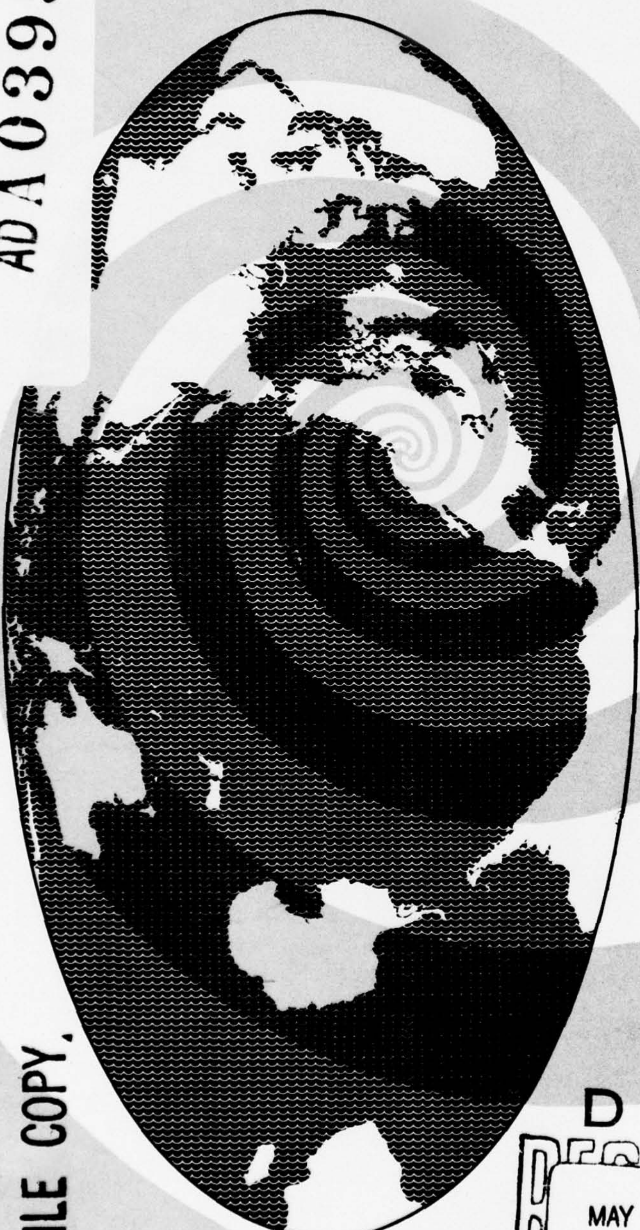
Technical Report No. 350

OBSERVATIONS OF WINDS AND CURRENTS IN HOOD CANAL



by

L.H. Larsen

Office of Naval Research
Contract N00014-75-C-0502-P00003

Reference M76-47
June 1976

seattle, washington 98195

UNIVERSITY OF WASHINGTON
DEPARTMENT OF OCEANOGRAPHY
SEATTLE, WASHINGTON 98195

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ACKNOWLEDGMENT

I gratefully acknowledge the able assistance received in all aspects of the program. The moorings were designed and prepared by Gary Peterson, who also shouldered the responsibilities for recycling instruments and monitoring the wind and tide gauges. He was assisted in this work by Stan Woods. The current meters were maintained by Dick Noble and Nungjane Shi. The computer portions of the work were handled by Diane Bowlin. I also thank Barbara Funke and Debbie BanDrosky for assistance in day to day problems and report preparation.

The moorings were installed using the research vessel ONAR operated by Gray Drewry and Troy Styron. I also thank all of the divers for their assistance with special thanks to Chief Mace for his efforts.

FOREWORD

This report contains selected portions of data collected in Hood Canal during the months of March 1976 through June, 1976. In the course of the study, 15 instruments were simultaneously measuring currents. The total amount of data collected amounts to approximately 4 years of data from a single instrument. This instrument sampled at 10 minute intervals. The shear volume of data collected precludes inclusion of the entire records in this document. Accordingly, we have selected portions of the data for presentation. Complete records are to be on file with the Naval Facilities Engineering Command (Mr. E. Escowitz) and on magnetic tape at the University of Washington (L. Larsen). Parties interested in this data are invited to contact either of the individuals listed above.

At this time, data is still being gathered. Synthesis of the data into perspective will require time. This report is not a synthesis, rather, it is examples presented at this early date in order that it be of assistance in meeting immediate engineering problems.

Hood Canal Conditions

This document is a report to the Navy on tidal currents in the vicinity of the refit facility at Bangor, Washington. It is prepared in fulfillment of contract N00014-75-C-0502 P00003.

Hood Canal is an arm of Puget Sound that forms the western part of the Sound. It is separated from the main basin by the Kitsap Peninsula, with its connection to the main portion of Puget Sound located some 20 km in from Admiralty Inlet. The constricted extrance to Hood Canal is 1-2 miles wide and about 12 miles long. Inside this entrance the main basin of Hood Canal is wider and appreciably longer. The investigation site, Bangor Wharf, is located about midway into the S-shaped entrance channel. Measurements were made in the cove separating Bangor Wharf from the spit immediately to the south, Keyport Bangor Pier (Figure 1).

The data input for this report comes from 5 moorings of Aanderra current meters, each mooring having 3 instruments. Currents were measured during the months of March, April, May, and June 1976. In addition, tide height, wind direction and magnitude were monitored at the Keyport Bangor Pier. An attempt was made to measure wind waves, however, malfunctioning of the instrument negated the data.

The location of the moorings are listed in Table 1 and their location illustrated in Figure 2.

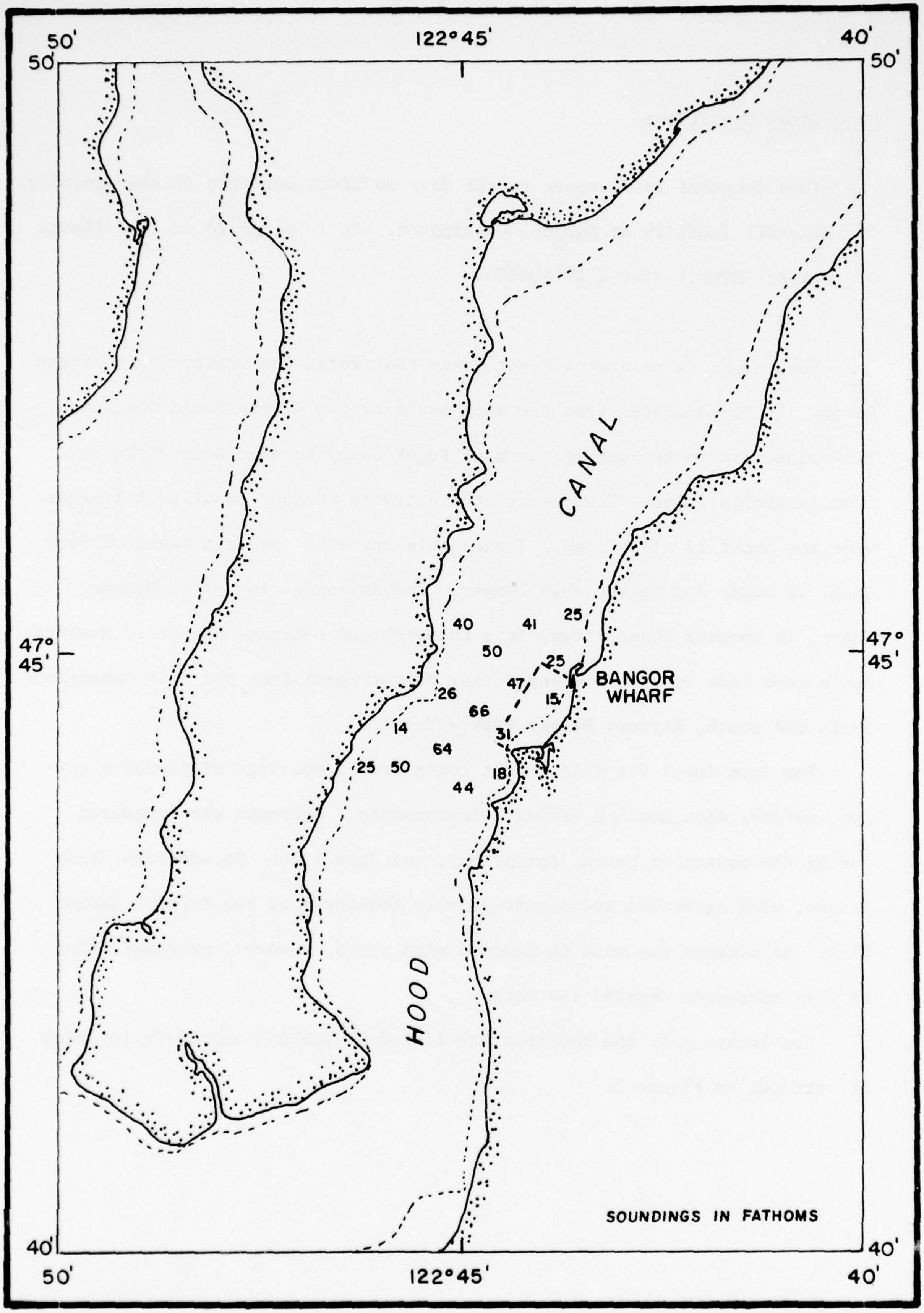


FIGURE 1. INVESTIGATION SITE.

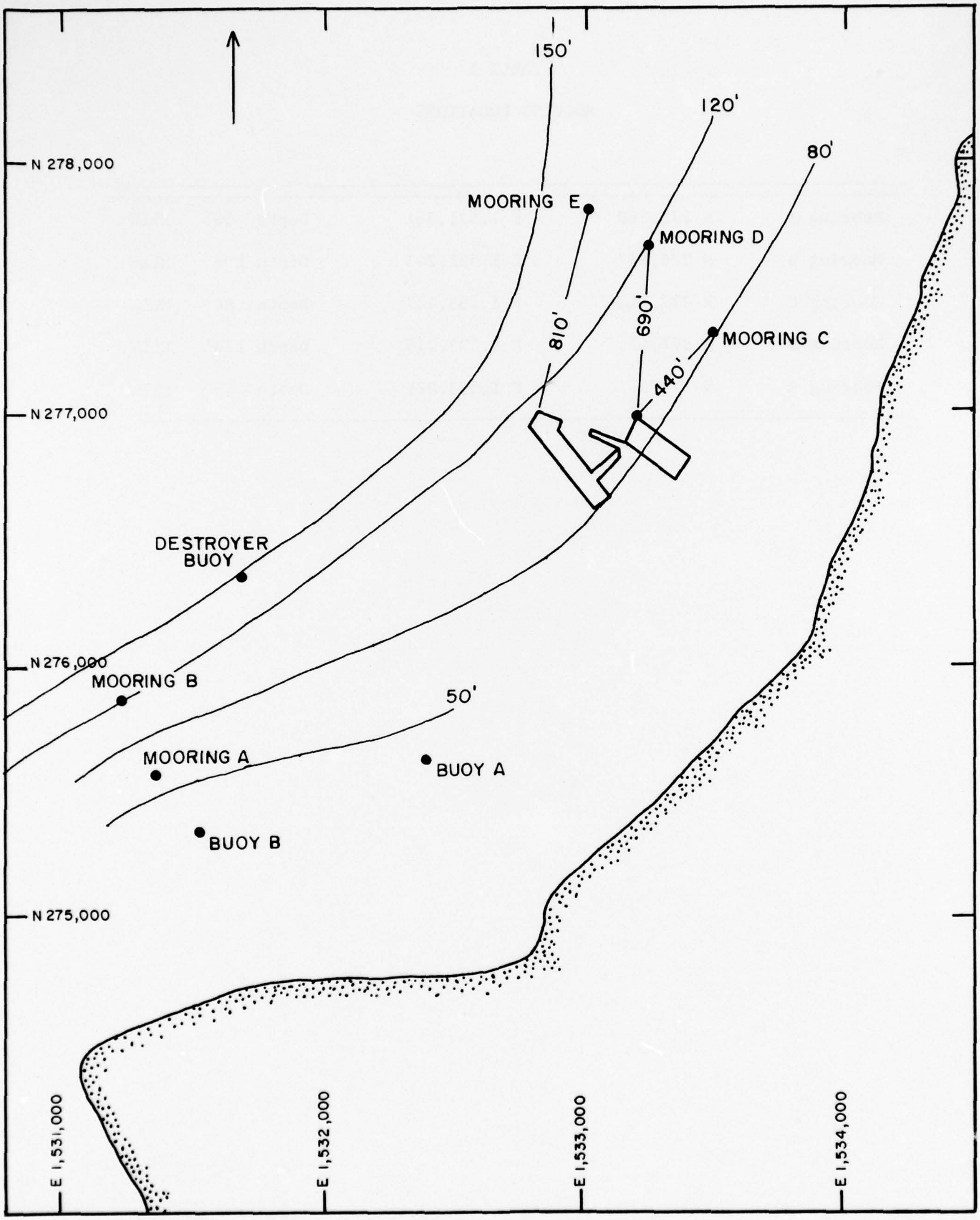


FIGURE 2. LOCATION OF MOORINGS.

TABLE 1

MOORING LOCATIONS

Mooring A	N 275,560	E 1,531,361	Depth 56'	MLLW
Mooring B	N 275,857	E 1,531,243	Depth 106'	MLLW
Mooring C	N 277,314	E 1,533,487	Depth 80'	MLLW
Mooring D	N 277,655	E 1,533,245	Depth 120'	MLLW
Mooring E	N 277,817	E 1,533,021	Depth 145'	MLLW

Current Meter Deployment

The current meters were installed on moorings -- the design of which is discussed in Appendix I. During the experiment, the current meters were periodically removed from their respective vanes, which are an integral component of the mooring, and taken ashore for refurbishment. A typical sequence was recovery on a Friday, refurbishment over the weekend, and re-installation on the mooring on the following Monday.

Each mooring contained 3 current meters whose nominal depths below the surface (MLLW) were 5, 10, and 15 meters. We designate the location of an instrument by a letter indicating the mooring and a number indicating the nominal depth. Thus, A 5 refers to mooring A and the instrument located approximately 5 meters below MLLW. In Table 2, we list the moorings and the Aanderra current meter number at each depth, the sample interval, and the dates during which the instrument was in the water.

TABLE 2

Mooring	Instrument	Sample Rate (min)	All Dates 1976 In Water	All Dates 1976 Out Water
A 5	1474	2	3 Mar	15 Mar
A 5	681	5	15 Mar	2 April
A 5	681	10	5 April	7 May
A 10	1475	2	3 Mar	15 Mar
A 10	1473	5	15 Mar	2 April
A 10	1473	10	5 April	7 May
A 15	1476	2	3 Mar	15 Mar
A 15	1776	5	15 Mar	2 April
A 15	1776	10	5 April	7 May
B 5	808	10	3 Mar	2 April
B 5	2053	10	5 April	7 May
B 5	2053	10	10 May	18 June
B 10	954	10	3 Mar	2 April
B 10	954	10	5 April	7 May
B 10	954	10	10 May	18 June
B 15	955	10	3 Mar	2 April
B 15	955	10	5 April	7 May
B 15	955	10	10 May	18 June
C 5	956	10	3 Mar	2 April
C 5	956	10	5 April	7 May
C 5	956	10	10 May	18 June
C 60	957	10	3 Mar	2 April
C 60	957	10	5 April	7 May
C 60	957	10	10 May	18 June
C 15	958	10	3 Mar	2 April
C 15	958	10	5 April	7 May
C 15	958	10	10 May	18 June
D 5	959	10	3 Mar	2 April
D 5	959	10	5 April	7 May
D 5	959	10	10 May	18 June

TABLE 2 (cont.)

Mooring	Instrument	Sample Rate (min)	All Dates 1976 In Water	All Dates 1976 Out Water
D 10	960	10	3 Mar	2 April
D 10	960	10	5 April	7 May
D 10	960	10	10 May	18 June
D 15	962	10	3 Mar	2 April
D 15	962	10	5 April	7 May
D 15	962	10	10 May	18 June
E 5	963	10	3 Mar	2 April
E 5	963	10	5 April	7 May
E 5	963	10	10 May	18 June
E 10	964	10	3 Mar	2 April
E 10	964	10	5 April	7 May
E 10	964	10	10 May	18 June
E 15	965	10	3 Mar	2 April
E 15	965	10	22 April	7 May
E 15	966	10	10 May	18 June

Calibration

Twenty-two Aanderaa current meters were involved in this project. These current meters and the source of the current meter are indicated in Table 3.

Table 3

Current Meter	Type	Owner	Press	Cond.	Temp.	Counter	Comments
681	RCM 4	NUSC	200	NO	YES	1:1	Uncalibrated
789	RCM 4	NUSC	NO	NO	YES		Unused
814	RCM 5	NUSC	5000	NO	YES		Unused
815	RCM 5	NUSC	500	NO	YES		Unused
1473	RCM 5	NUSC	8000	NO	YES	1:1	Calibrated
1474	RCM 5	NUSC	8000	NO	YES	1:1	Calibrated
1476	RCM 5	NUSC	NO	NO	YES	1:1	Calibrated
1776	RCM 5	NUSC	5000	NO	YES	1:1	Calibrated
954	RCM 5	NFEC	8000	NO	YES	6000:1	Calibrated
955	RCM 5	NFEC	8000	NO	YES	6000:1	Calibrated
956	RCM 5	NFEC	200	NO	YES	6000:1	Calibrated
957	RCM 5	NFEC	8000	NO	YES	6000:1	Calibrated
958	RCM 5	NFEC	8000	NO	YES	6000:1	Calibrated
959	RCM 5	NFEC	8000	NO	YES	6000:1	Calibrated
960	RCM 5	NFEC	8000	NO	YES	6000:1	Calibrated
962	RCM 5	NFEC	8000	NO	YES	6000:1	Calibrated
963	RCM 5	NFEC	200	NO	YES	6000:1	Calibrated
964	RCM 5	NFEC	3000	NO	YES	6000:1	Calibrated
965	RCM 5	NFEC	3000	NO	YES	6000:1	Calibrated
808	RCM 4	NCEL	500	NO	YES	6000:1	Calibrated
2053	RCM 4	U W	500	YES	YES	4:1	Uncalibrated

Comments on Table 3.

NUSC = Naval Undersea Systems Command

NFEC = Naval Facilities Engineering Command

NCEL = Naval Civil Engineering Laboratory

U W = University of Washington

Calibration, Calibrated by Northwest Regional Calibration Center, 300 120th Ave. Northeast, Bellevue, Washington 98005.

The calibration consisted of temperature, compass direction and a check of rotor speed and instrument output. The speed calibration is not a true calibration. Pressure was not calibrated because the depth range of the majority of the sensors was so large as to render them useless for tide information. The low pressure sensors on meters 956 and 963 were installed during the first refurbishment of these instruments and thus could not be calibrated. Factory calibrations were used where no calibration was performed by NOAA.

Data Analysis

Upon removal from the current meters, the magnetic tapes were taken to the tape reading facility owned by NOAA and located at their Sand Point, Seattle facility. The fragile ½ mil tapes on the current meters were immediately duplicated into 1½ mil inch tape in order that the original tapes be read only once. The duplicate tapes were than read and the output recorded on a six channel strip chart recorder. Both channels of the Aanderra tape were read on the strip chart recorder. The channel exhibiting the best signal (fewest error records) was selected. This selected channel was then recorded on 9-track tape compatible with the CDC system in operation on the University of Washington campus.

This tape was read on the CDC using a standard NOAA program. The output of this program is a listing of all data points as recorded and the currents, temperature, pressure, etc., as derived from the original data from calibration formulae. This listing also contains error signals which indicate where data were lost or where problems exist on the tape. The listing is gone through by hand and edited.

An edited tape is then made from which all further numerical work is performed.

<u>Tidal Flow</u>

The general nature of the flow in the cove is illustrated in Figures 3A - 3E. This sequence is for 13 April, 1976, a time period marking the initiation of the spring tide cycle. At 0000 13 April, the tide is rising and about half way to the maximum from the previous low water. The tide elevation (Seattle) was maximum (12 ft) at 0300 and a minimum (.3 ft) at 0950. The next high water was at 1600.

At 0000 the current is flooding at all moorings. The flow pattern is a streaming of water into the cove from the north and exiting to the south. Currents and sites D and E are on the order of .5 to .6 knots and at A and B about .8 kt. By 0100 the currents wave increased at D and E to .8 kt and at C from .3 to .6 kt. The currents then diminish as high water is neared dropping to an average of .5 kt at D and E. At high water the flow has reversed at C while still flooding at D and E. This pattern is a result of the formation of an anticyclonic eddy in the cove. An hour after high water, the eddy has been swept from the cove and a weak flood is still in progress. Two hours after high water the currents are ebbing at C, D, and E, while we still have a weak flood at A and B. We speculate that water piles up in the cove and that those currents represent an outflow of this water which occurs following high tide. The times referred to are based on Seattle tides.

A tide gauge was established at Keyport Bangor Pier for the purpose of comparison with Seattle tides. The conclusions after comparing with Seattle tides are that the range of the tide is .4 feet less at Bangor and that high water occurs 1 hour earlier at Bangor than Seattle, while low water occurs ½ hour earlier at Bangor. Thus, the rise of the tide is faster at Bangor than Seattle. In the shallower waters of Hood Canal greater asymmetry in the tides is expected.

Three hours after high water, the ebb is in full force with 1.1 kts registering at B, .75 at E, .7 at D, and .5 at C. At 0700, three hours before low water, the ebb has weakened slightly. Two hours before low water, the flow into the cove at A and B has dropped to near zero while a stronger ebb is still in progress to the north. The flow at A and B then increases again 1 hour before low water. At low water, the flow rate is small everywhere in the cove. One hour after low water, it floods the strongest at A (1.1 kt) and the currents at C exceed those at D and E. From this time onward the pattern repeats itself. While the pattern is discussed only for the 13 April date, this cycle repeats throughout all records.

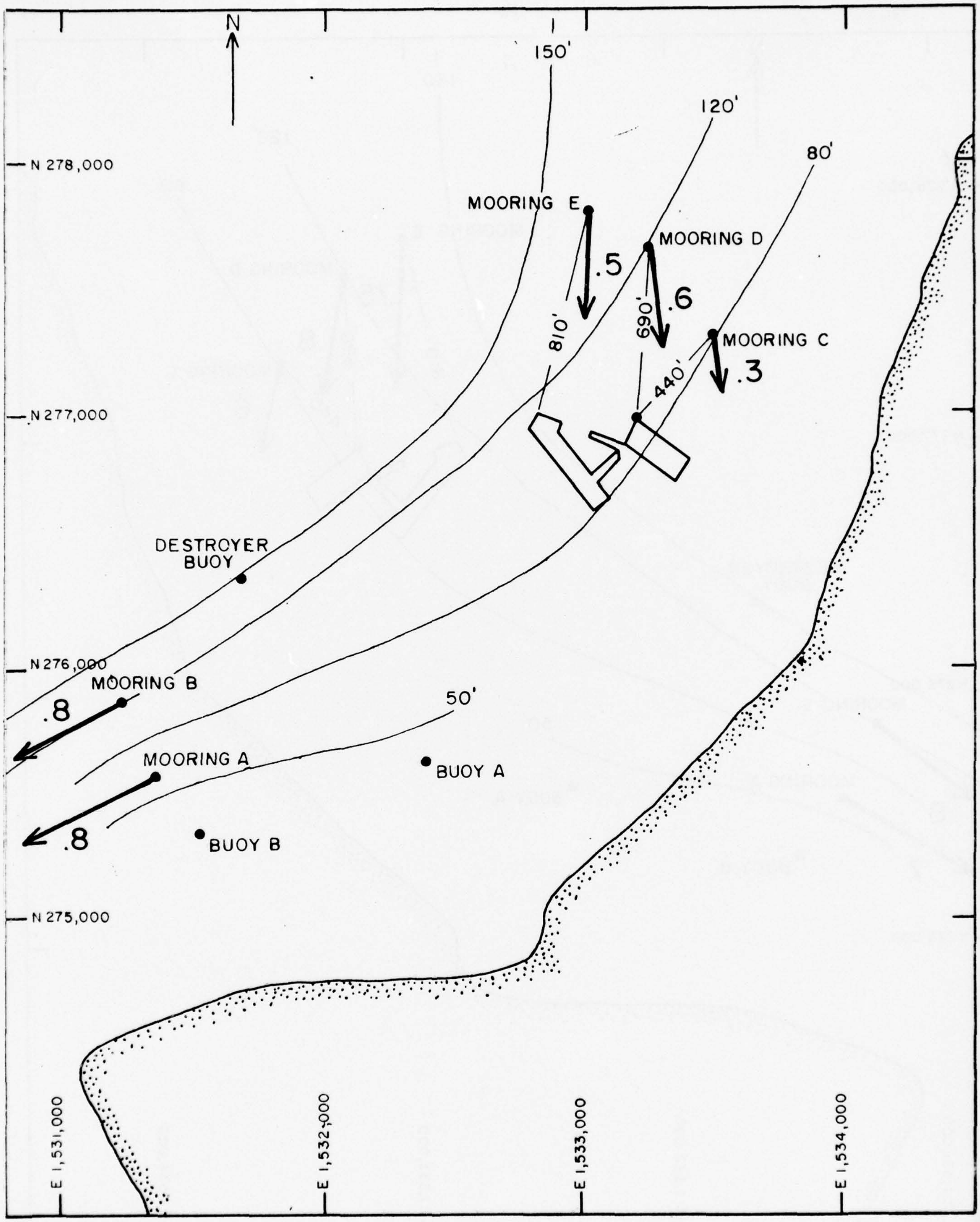


FIGURE 3A. TIDAL FLOW, 0000 13 APRIL 1976.

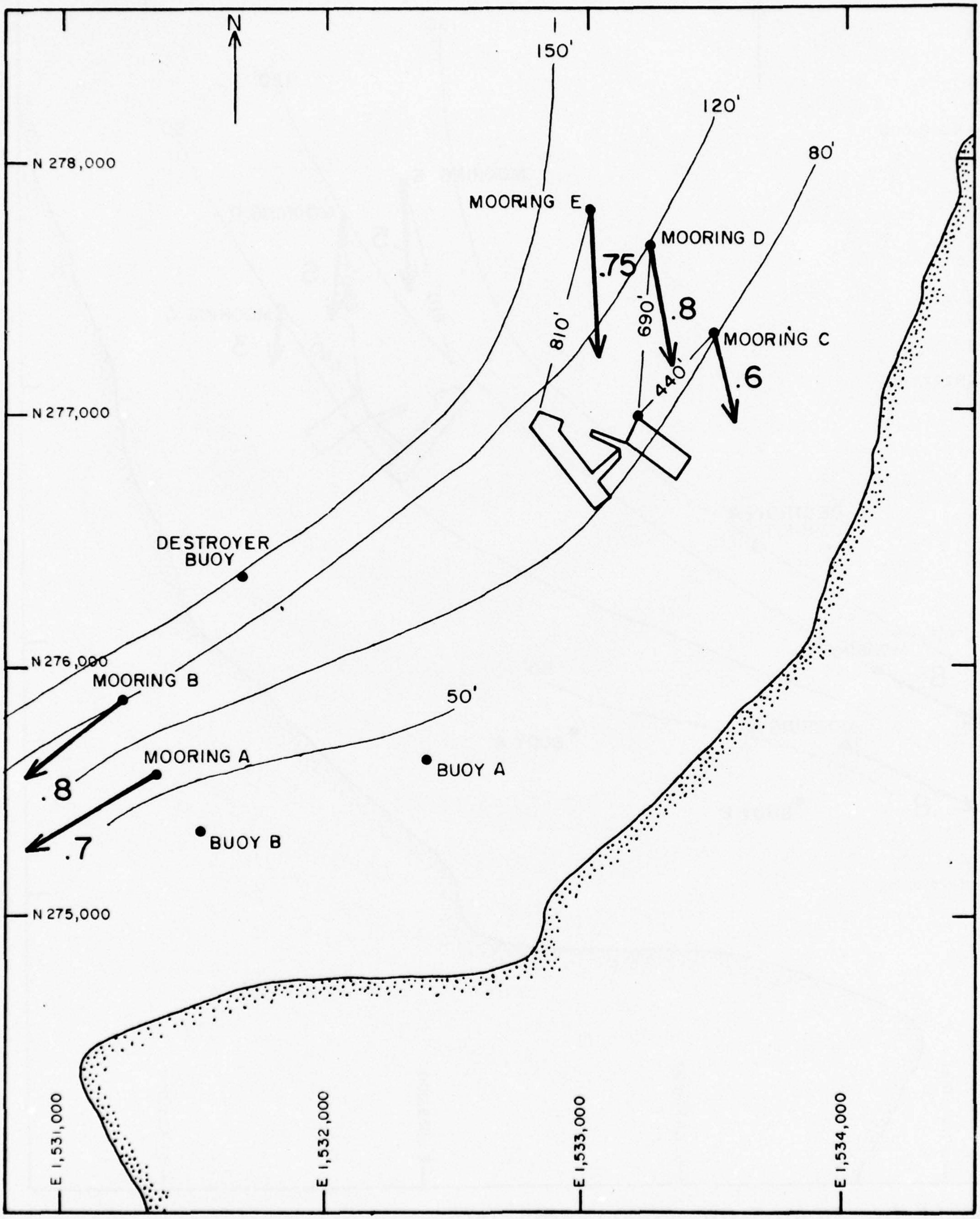


FIGURE 3B TIDAL FLOW, 0100 13 APRIL 1976.

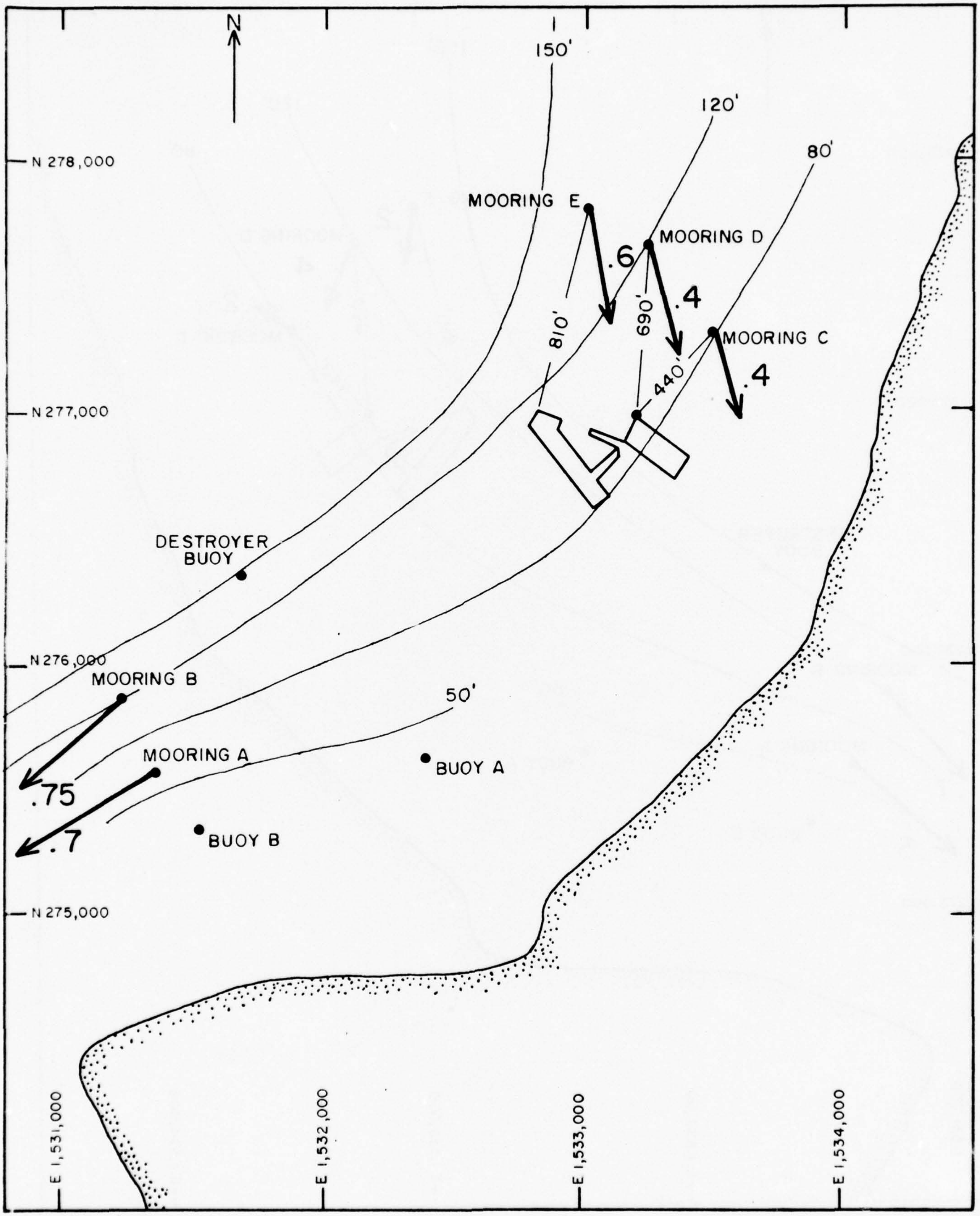


FIGURE 3C. TIDAL FLOW 0200 13 APRIL 1976.

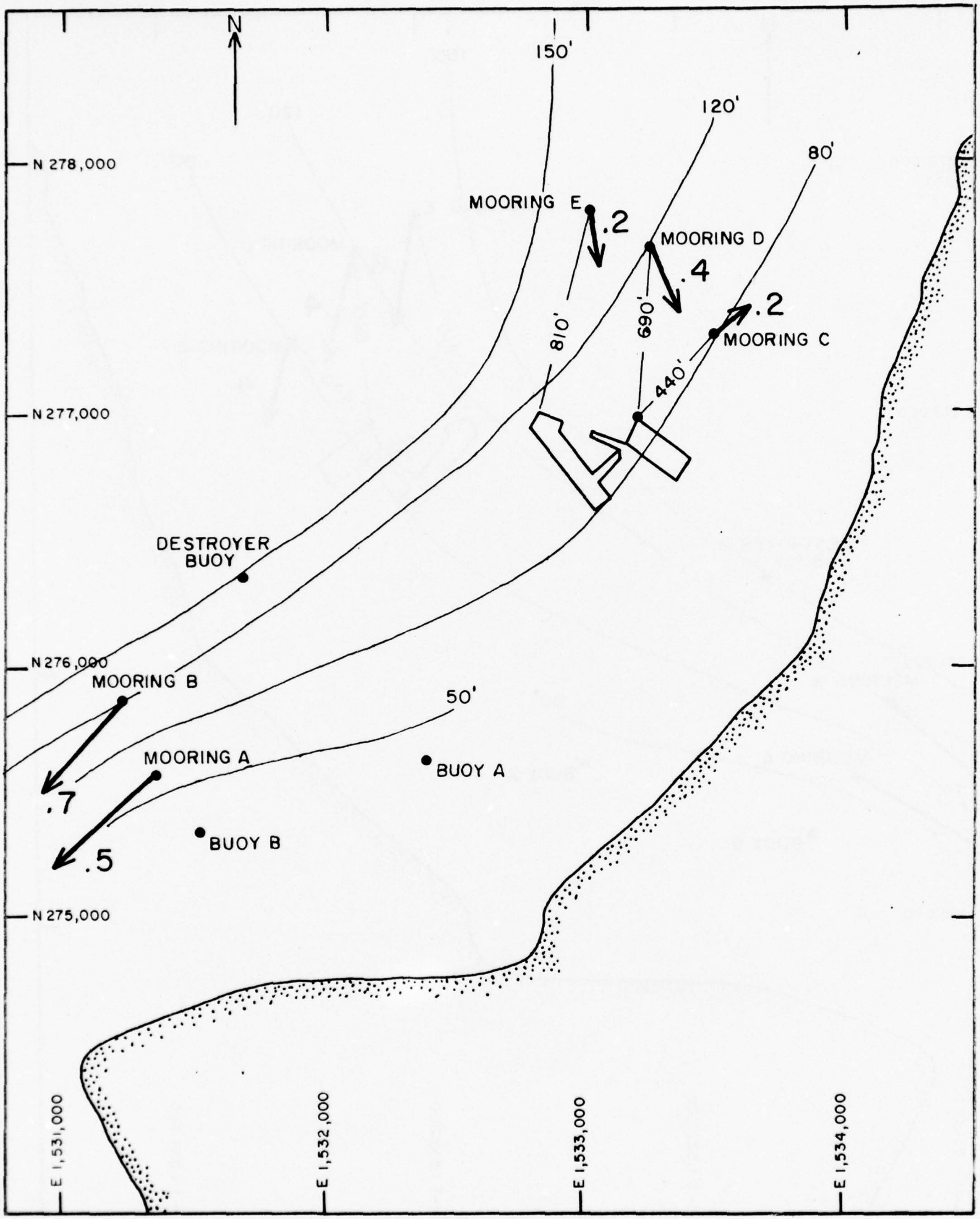


FIGURE 3D. TIDAL FLOW 0300 13 APRIL 1976.

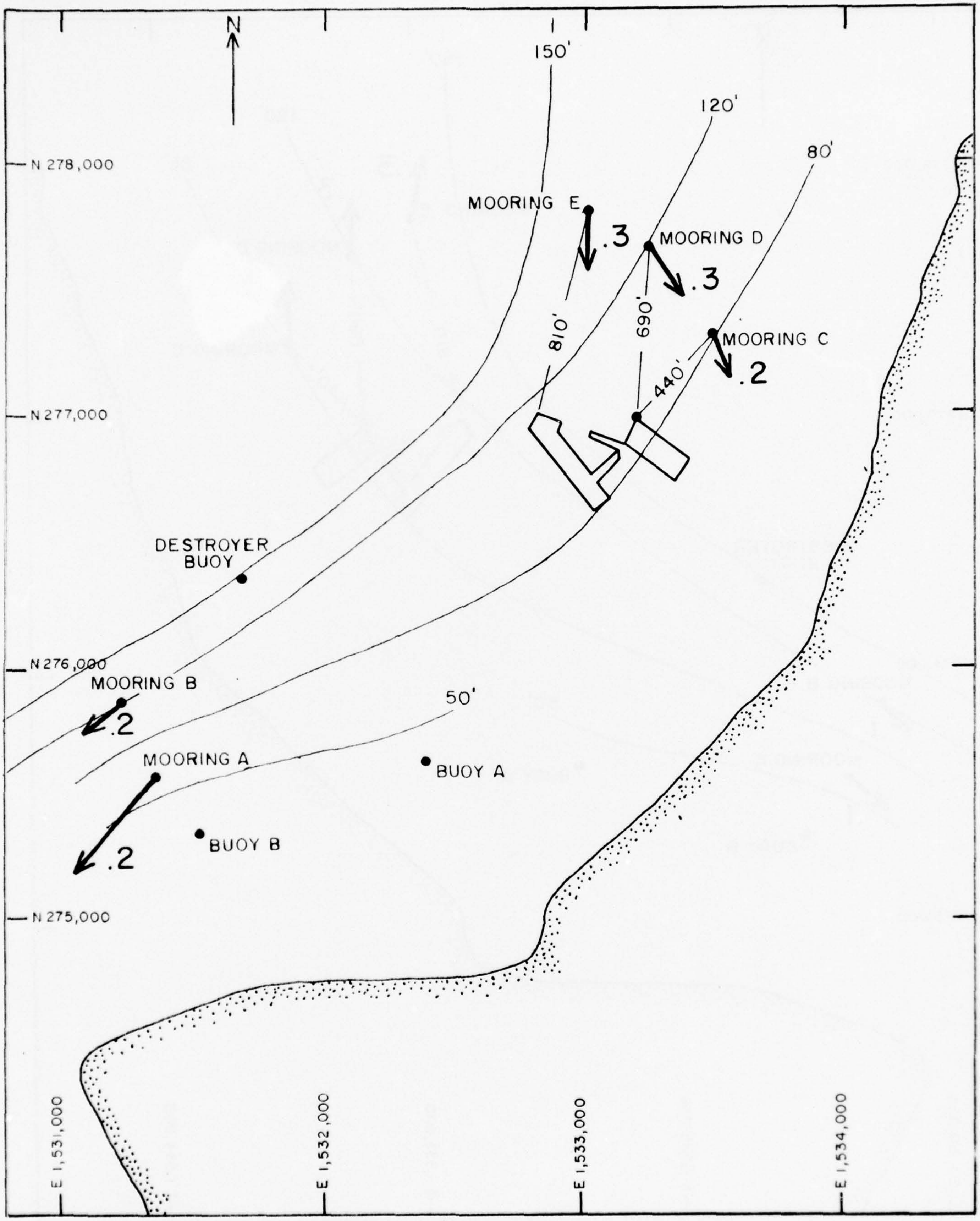


FIGURE 3E. TIDAL FLOW, 0400 13 APRIL 1976.

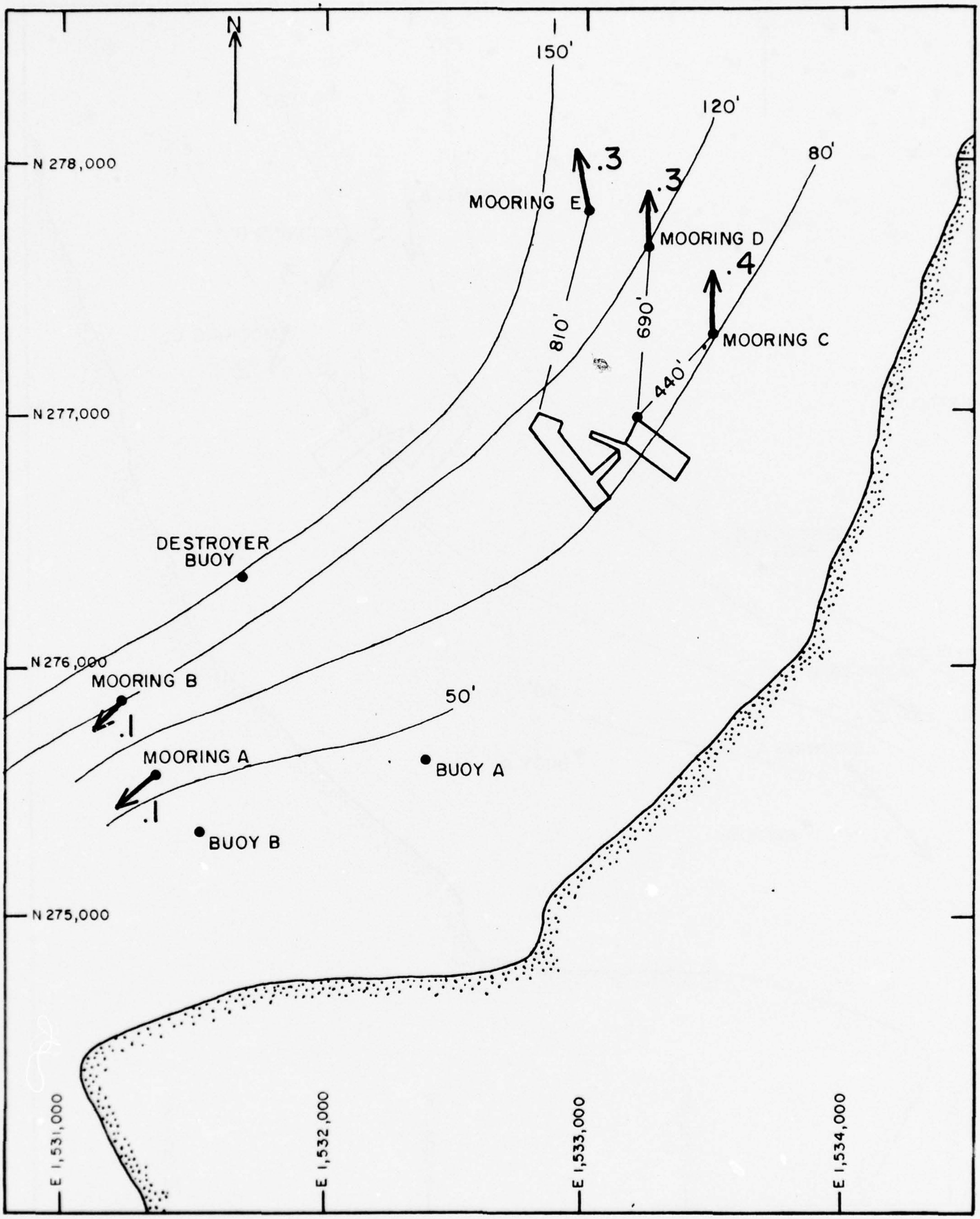


FIGURE 3F. TIDAL FLOW 0500 13 APRIL 1976.

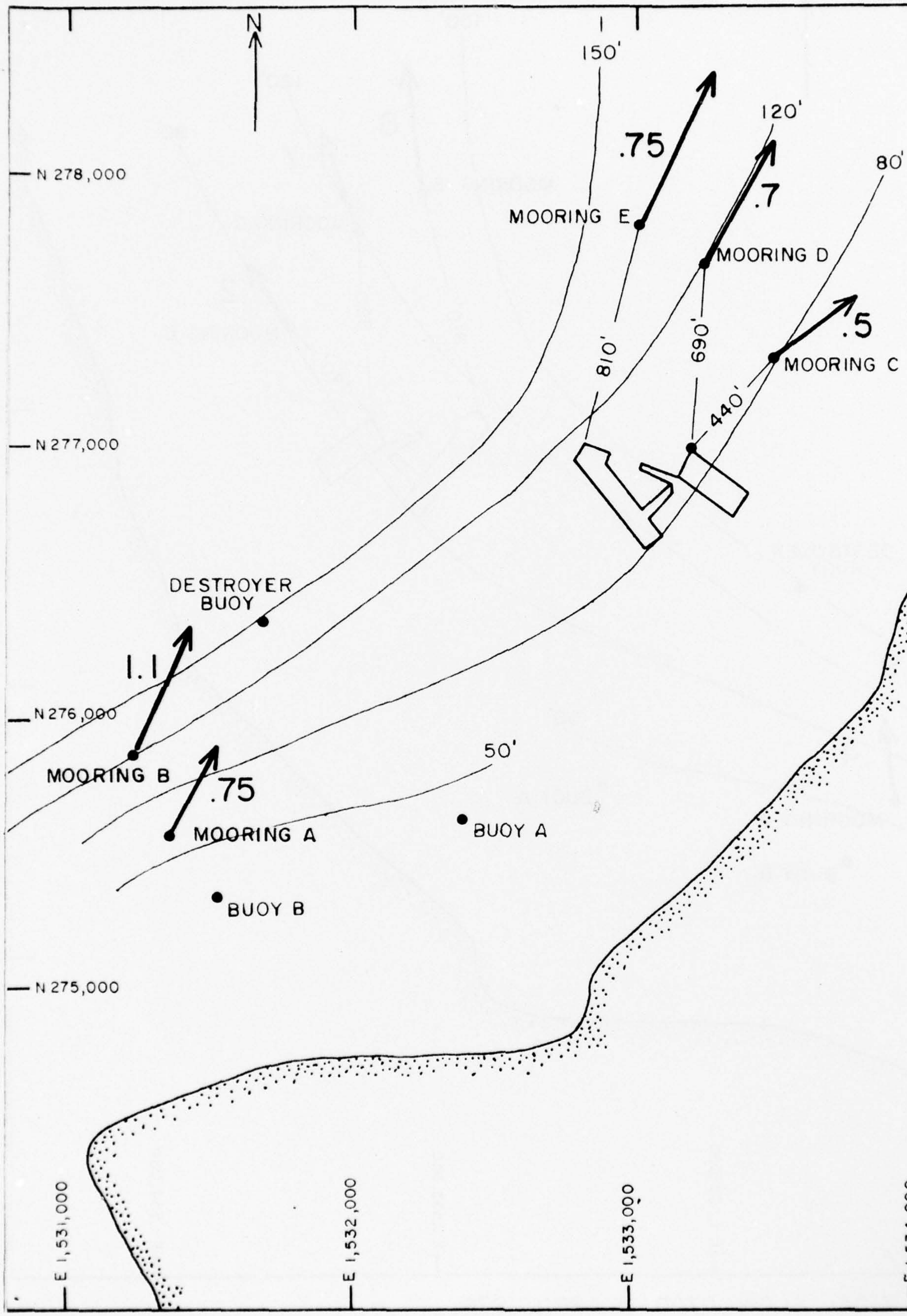


FIGURE 3G. TIDAL FLOW 0600 13 APRIL 1976.

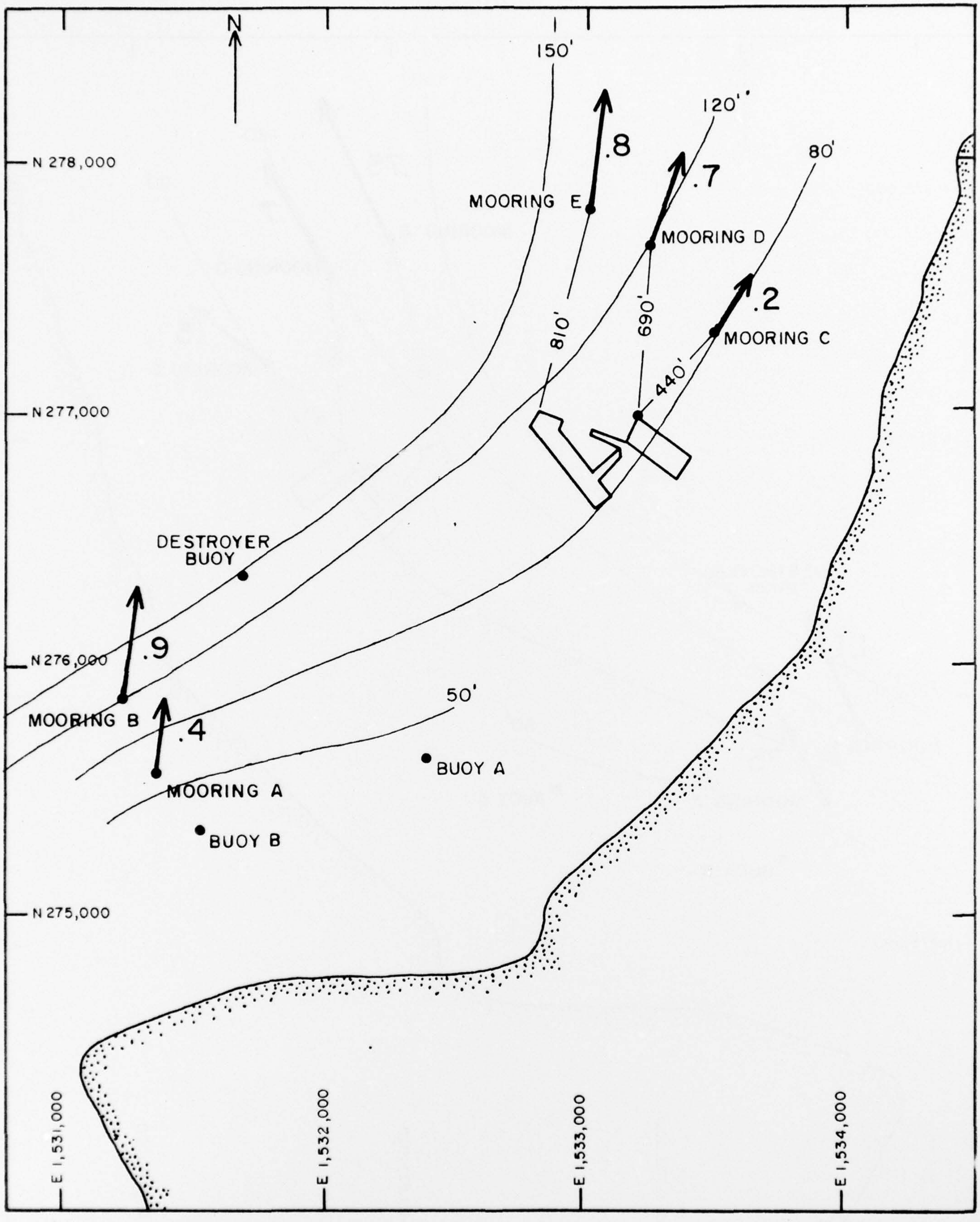


FIGURE 3H. TIDAL FLOW 0700 13 APRIL 1976.

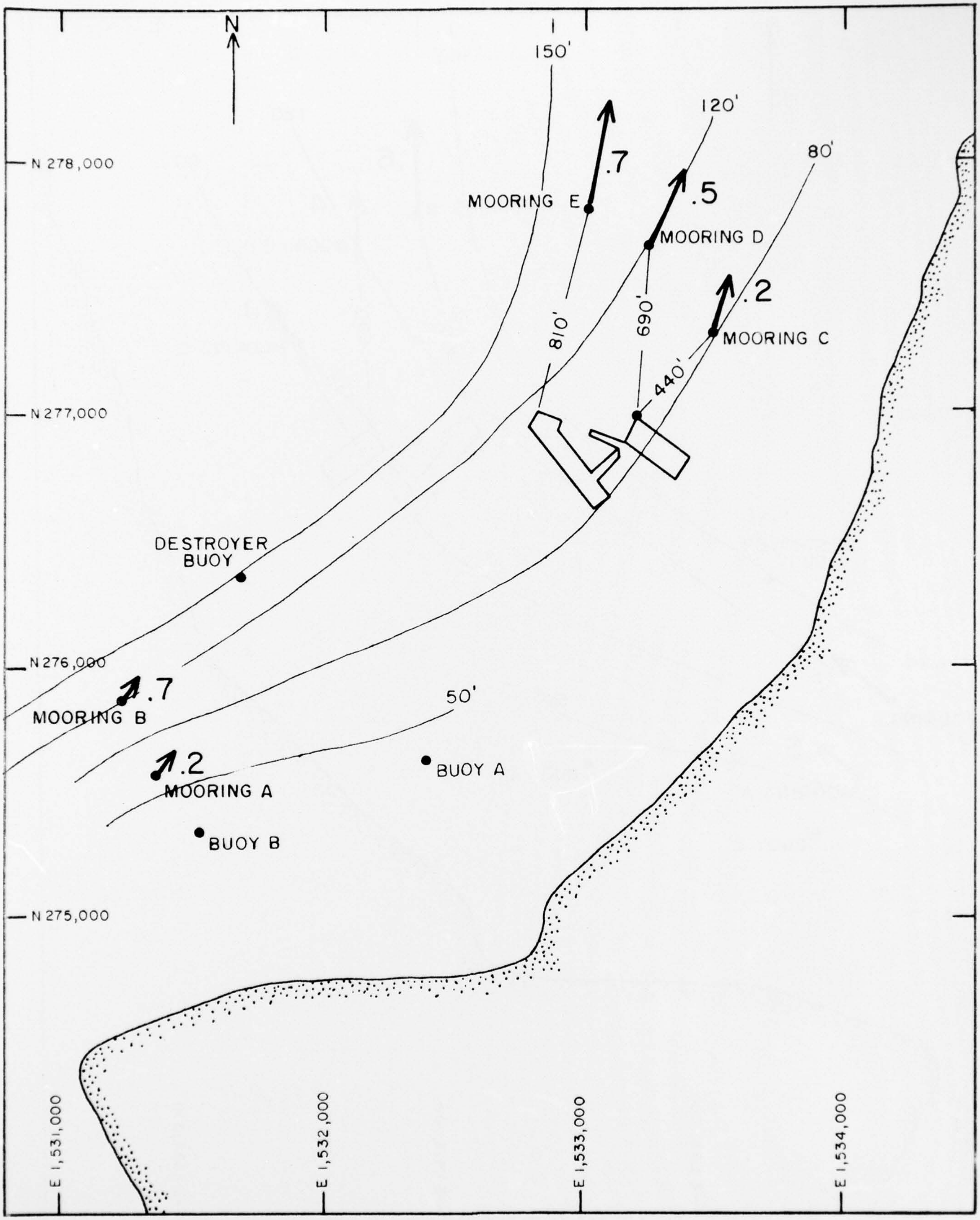


FIGURE 31. TIDAL FLOW, 0800 13 APRIL 1976.

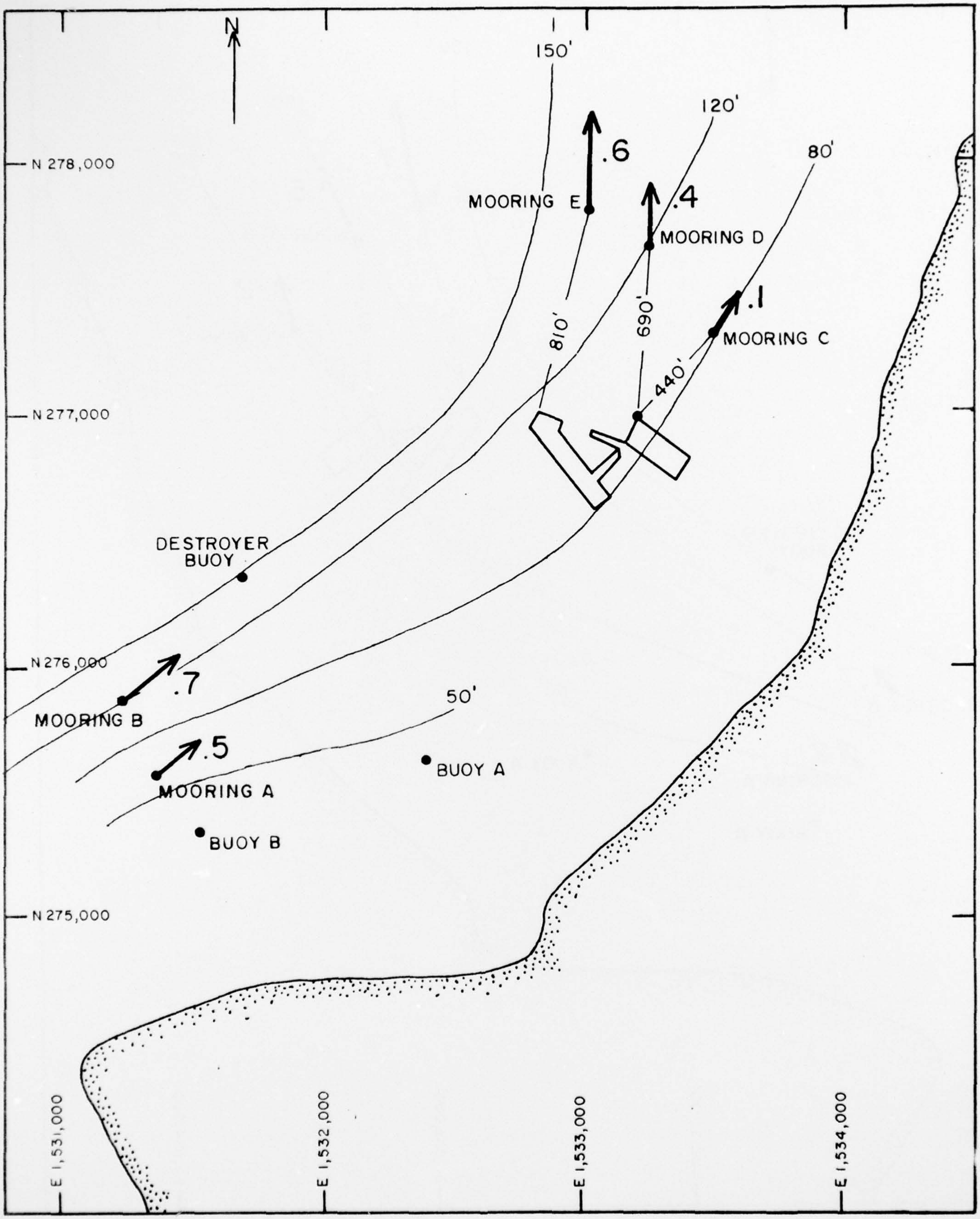


FIGURE 3J. TIDAL FLOW, 0900 13 APRIL 1976.

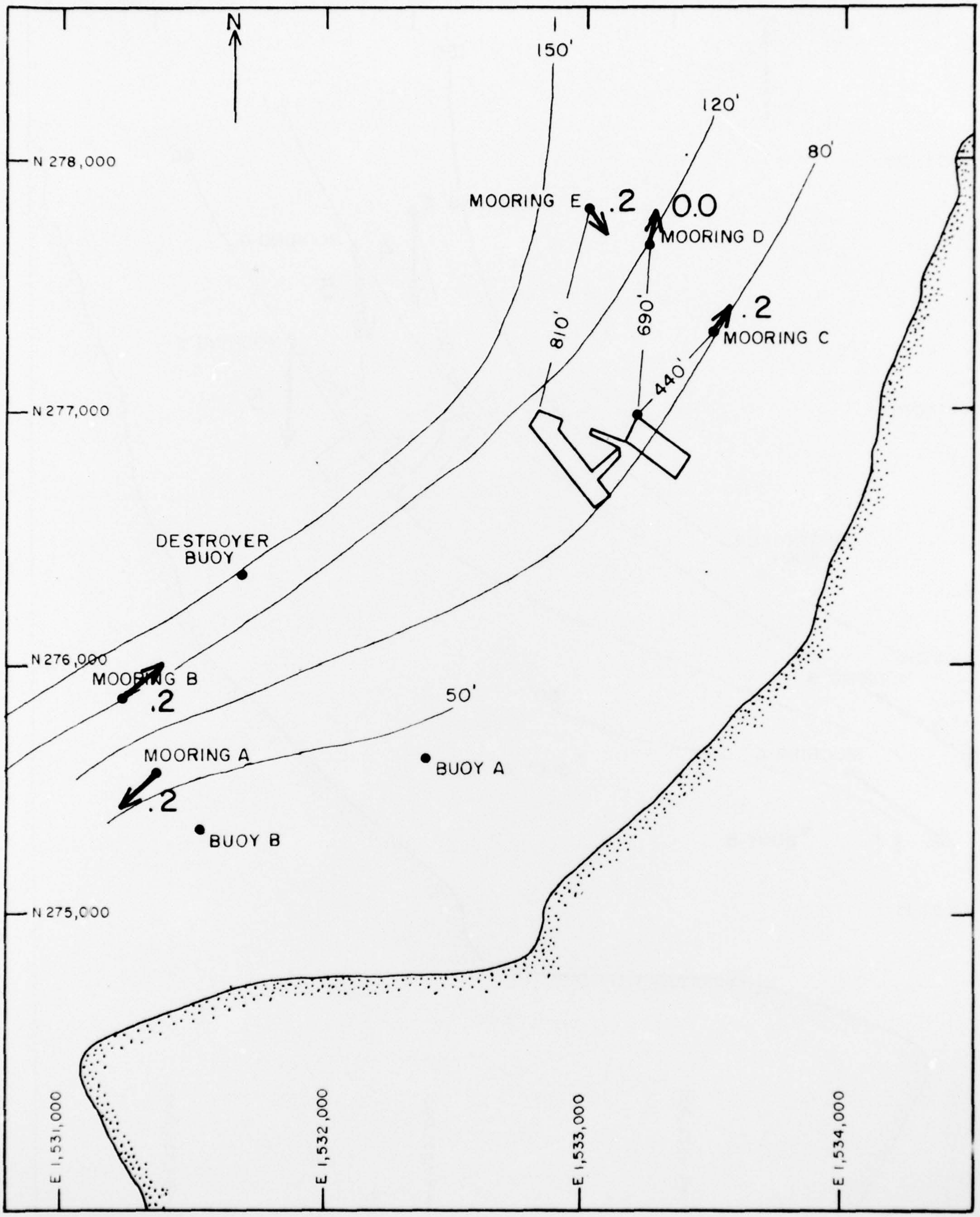


FIGURE 3K. TIDAL FLOW. 1000 13 APRIL 1976.

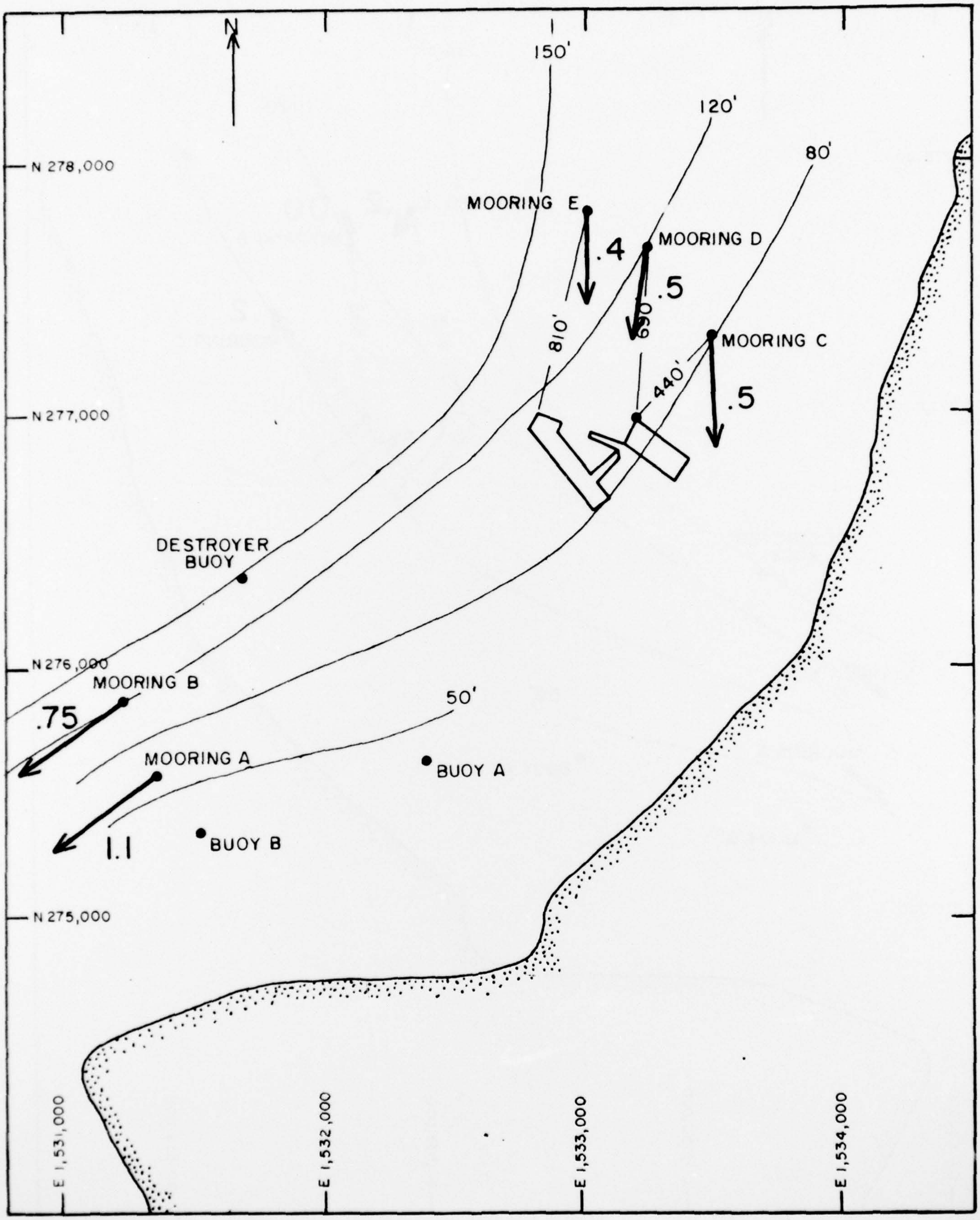


FIGURE 3L. TIDAL FLOW. 1200 13 APRIL 1976.

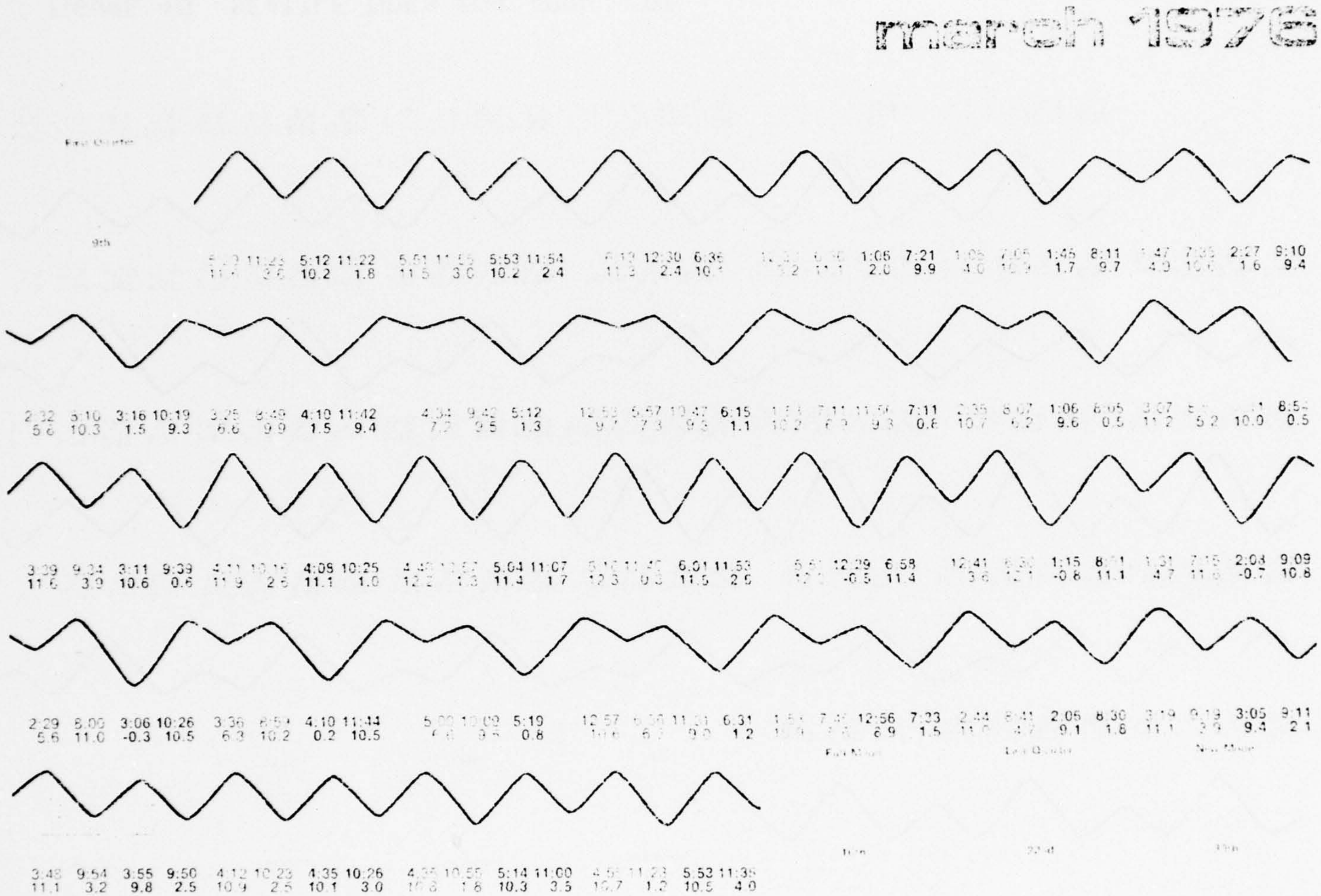


FIGURE 4A SEATTLE TIDES FOR MARCH, 1976.

april 1976

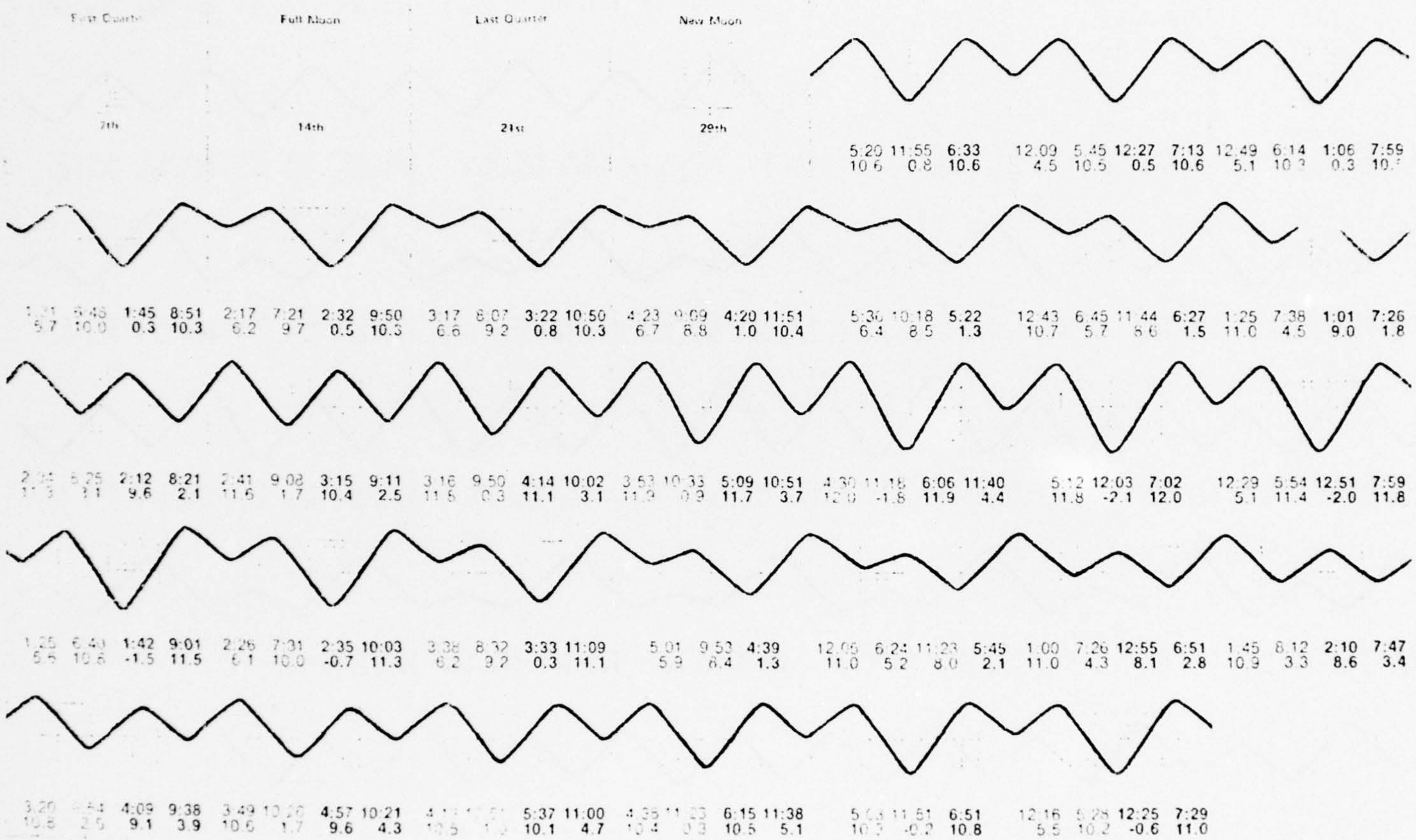


FIGURE 4B SEATTLE TIDES FOR APRIL, 1976.

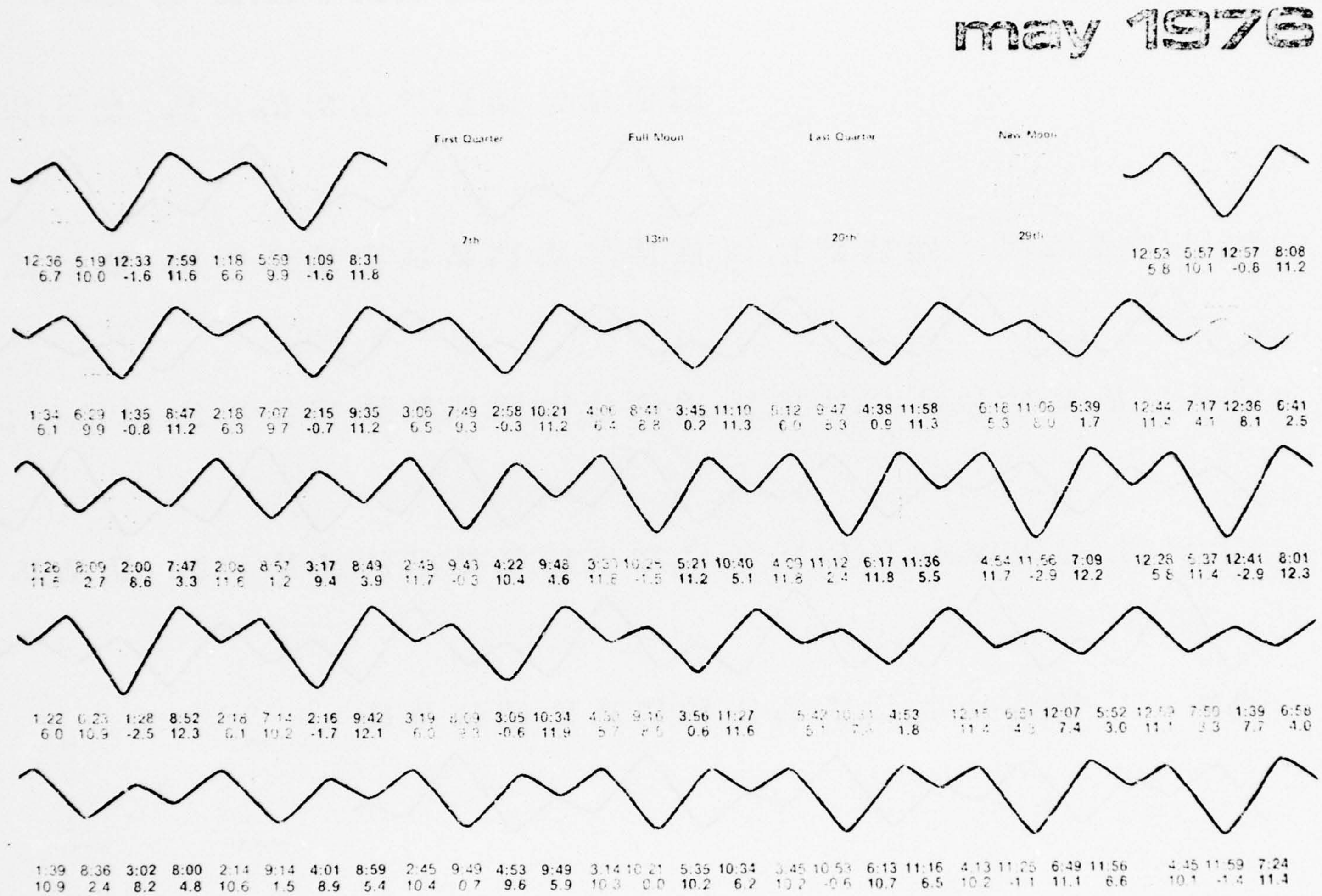


FIGURE 4C SEATTLE TIDES FOR MAY, 1976.

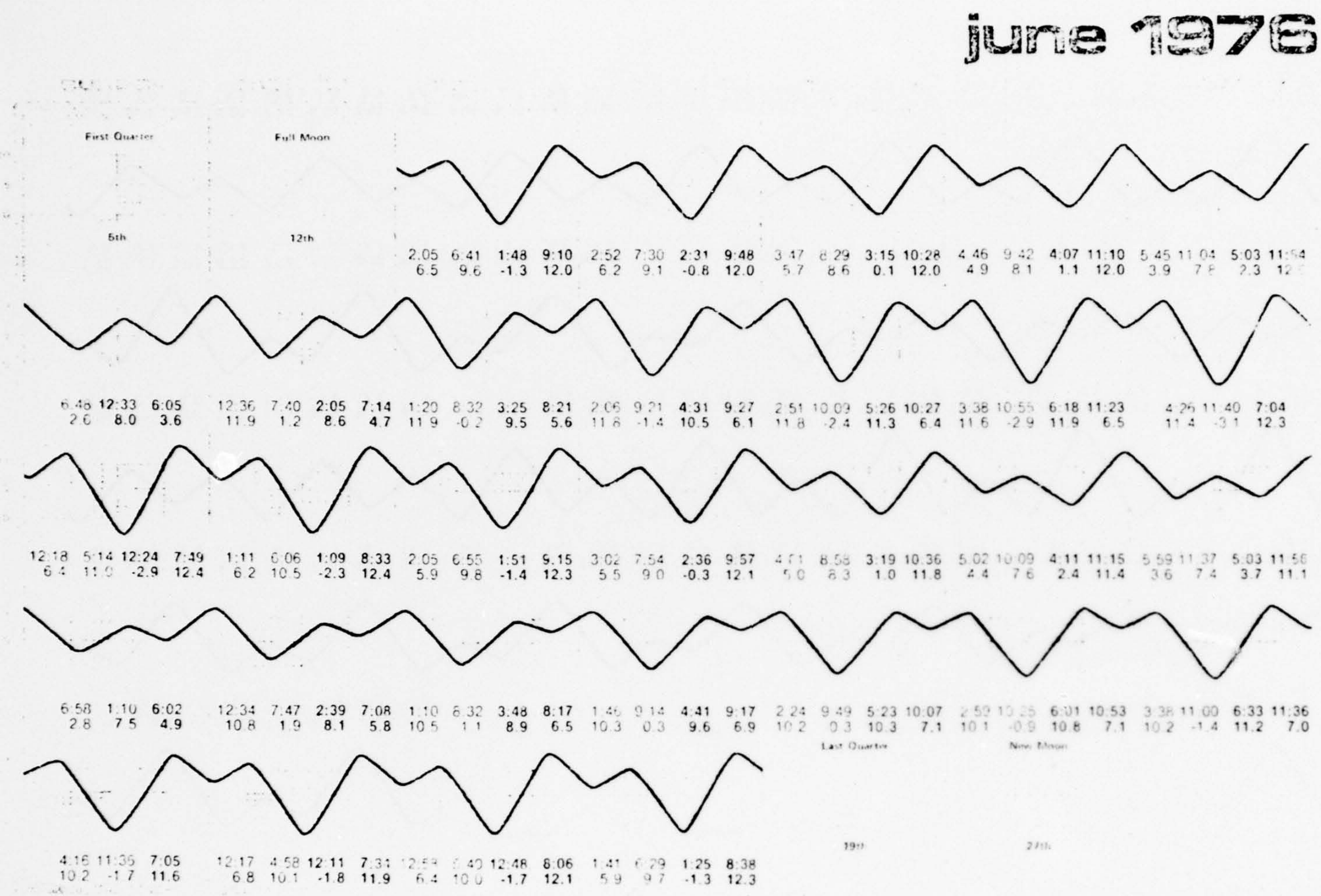


FIGURE 4D SEATTLE TIDES FOR JUNE, 1976.

Moorings and Instruments

Tides

Tidal elevations were measured with a Fischer-Porter Model 1550 automatic digital tide gauge. A length of 2½" PVC pipe was affixed vertically to a piling at the Keyport Bangor Pier. At the base of the PVC pipe there is a rubber insert that prevents water from rapidly entering the base of the pipe. This provides damping so that surface waves will not influence the waterlevel in the pipe. The Fischer-Porter tide gauge is installed directly over the pipe and a float suspends from the gauge directly into the pipe. Changes in water level raise and lower the float and these variations are recorded on paper tape providing the desired tide data.

Winds

Winds were measured with a Meteorological Research Inc. Model 1072 portable weather station. This instrument was installed on the Keyport Bangor Pier at an exposed location. Wind speed is measured with a cup anemometer and direction with a vane. This instrument has a strip chart recorder on which the data is stored.

Moorings

The design of the moorings is indicated in Figure A1. All moorings were identical except for the length of line between the lower swivel and the bottom current meter. This length was adjusted for the water depth of each mooring. Upon retrieval almost 4 months after installation, the moorings were in sound condition, not having been harmed by the environment. The only corrosion problems that we had were with the Aanderra current meters.

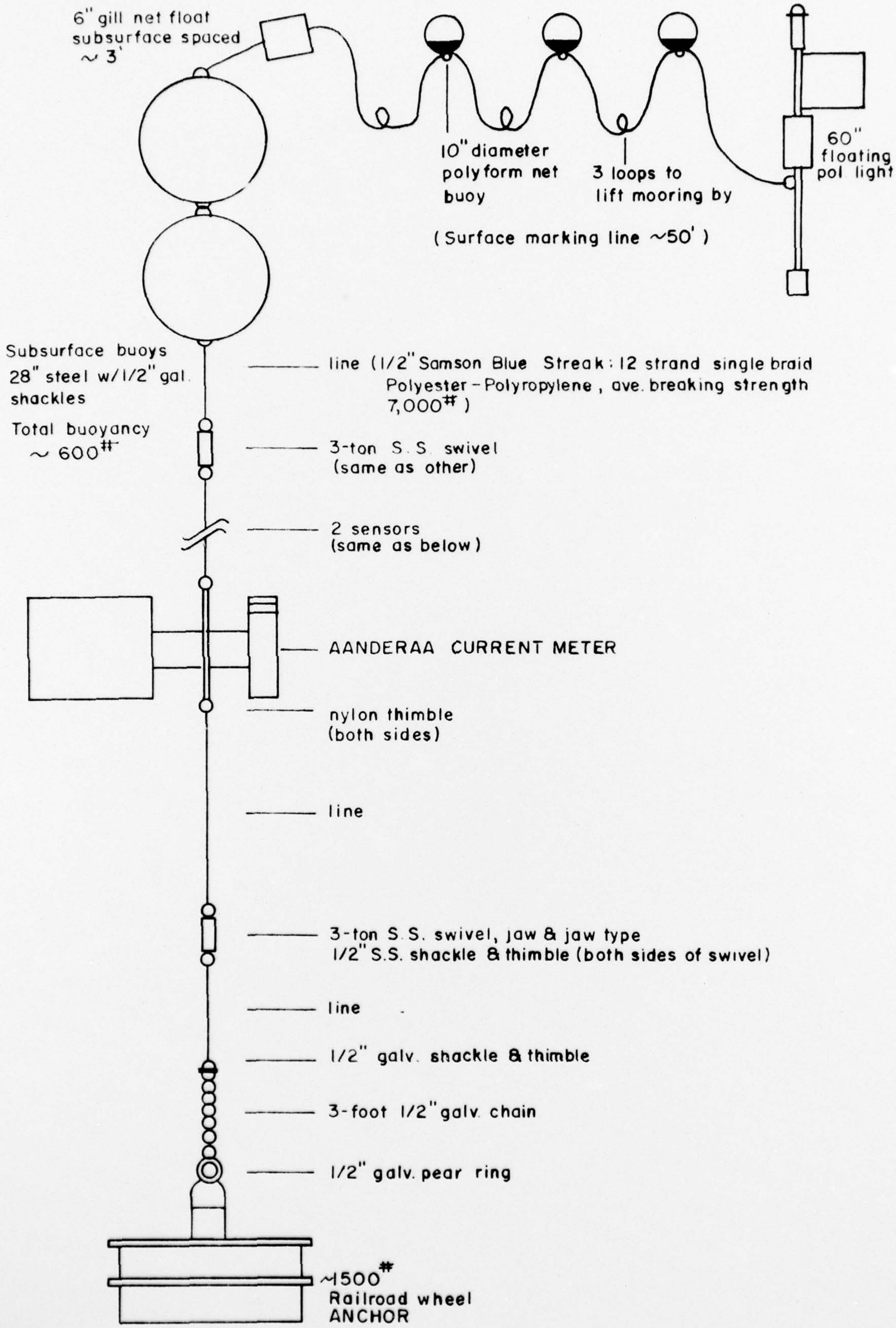
The zinc's corrode rapidly and need to be replaced each time the instruments are recycled.

In Table A1 we indicate the lengths of each line element in the moorings. The lengths are for dry line stretched to 600 lbs of tension. We number the lines as they occur downwards from the floats. Line 1 is between the float and the top swivel. Line 2 between the top snivel and the top current meter, down to Line 6 which is bewteen the bottom swivel and the anchor chain. The units of length are inches unless otherwise indicated.

TABLE A1

	MOORING					
	A	B	C	D	E	
Line 1	27.5	27	28	27	28.25	
Line 2	27.5	27.5	26.5	26.5	26	
Line 3	136	135	134	133.5	139.5	Unstretched (allow 6% stretch)
Line 4	136.5	135	134.5	135.25	136	
Line 5	24	46 ft	23 ft	60 ft	80 ft	
Line 6	28	41	39	36.5	42.5	

During installation the depth was monitored and the top current meter was at a depth of 17 ± 2 ft below MLLW on all moorings.


6" gill net float
subsurface spaced
~ 3'
10" diameter
polyform net
buoy
3 loops to
lift mooring by
60"
floating
pol light
(Surface marking line ~50')
Subsurface buoys
28" steel w/1/2" gal.
shackles
Total buoyancy
~ 600#
line (1/2" Samson Blue Streak: 12 strand single braid
Polyester - Polypropylene, ave. breaking strength
7,000#)
3-ton S.S. swivel
(same as other)
2 sensors
(same as below)
AANDERAA CURRENT METER
nylon thimble
(both sides)
line
3-ton S.S. swivel, jaw & jaw type
1/2" S.S. shackle & thimble (both sides of swivel)
line
1/2" galv. shackle & thimble
3-foot 1/2" galv. chain
1/2" galv. pear ring
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Current meter data
Hood Canal
Puget Sound

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report contains selected portions of data collected in Hood Canal during the months of March 1976 through June 1976. In the course of the study, 15 instruments were simultaneously measuring currents. The total amount of data collected amounts to approximately 4 years of data from a single instrument. This instrument sampled at 10 minute intervals. The shear volume of data collected precludes inclusion of the entire records in this document. Accordingly, we have selected portions of the data for presentation. are presented.

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